This paper emphasizes the efficiency characteristics of alternative competitive bidding mechanisms, but also discusses how different elements of the auction environment affect the seller's revenue.[20] Thus, this paper will analyze principally the ability of auctions to maximize consumer and producer surplus (i.e., economic efficiency). The use of economic efficiency as the basis for ranking alternative assignment mechanisms is firmly grounded in social welfare theory. An economically efficient competitive bidding mechanism assigns spectrum to the bidder with the highest valuation for spectrum, given current use restrictions imposed by the Commission.[21] Such spectrum would be devoted to its most highly valued use.[22] This, in turn, ensures

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[20] This paper recognizes that the Commission must consider small businesses, rural telephone companies, and businesses owned by women and minorities in formulating the rules determining the winning bidder. Because it is unclear how the available preference schemes affect the efficiency rankings of alternative auctions, this paper does not judge alternative auction forms on their ability to satisfy this statutory directive.

[21] In order for the assignment to be economically efficient, this valuation must be net of cost.

[22] This assumes that there exists a strong correlation between social welfare and private welfare. See S. Borenstein, On the Efficiency of Competitive Markets for Operating Licenses, Quart. J. Econ. 357-85 (1988). In theory, there are situations in which private incentives will lead to excessive levels of investment. See Mankiw & Whinston, Free Entry and Social Inefficiency, 17 RAND J. of Econ. 48-58 (1986). On the other hand, the inability of firms to capture surplus from inframarginal consumers will cause private incentives to lead to insufficient levels of investment. The net effect of these two incentives has never been analyzed empirically. Indeed, few economists believe that either of these two effects creates a presumption in favor of administrative procedures to regulate private sector entry and

that social welfare could not be enhanced by any re-allocation of spectrum among users.

Considerable theoretical analysis also has been conducted on how to maximize the seller's revenue in a single-unit auction environment. In many instances, attempts to maximize revenue will also maximize economic efficiency. However, in many instances, the objectives of revenue maximization and economic efficiency diverge. This divergence is due to certain tools that sellers sometime employ for the purpose of obtaining additional revenue from bidders. For example, sellers often impose a "reserve price" (i.e., a minimum acceptable price) when auctioning an item.[23] The reserve price may serve to extract a slightly higher price from the bidder with the highest valuation for the item at auction. In an English auction, the seller only receives an amount just over the second highest valuation placed on the object. The seller is capable of extracting additional surplus from the winning bidder with a reserve price that lies in between the first highest and second highest valuation. However,

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investment decisions.

[23] The seller selects a reserve price prior to the start of the auction and attempts to keep it unknown to bidders. Because of the seller's interest to keep it unknown, bidding in an English auction often starts below the reserve price. A reserve price is not the same as the price below which a seller would be unwilling to sell the item. Economic theory indicates that a seller should set a reserve price that is strictly higher than the minimum price for which a seller would sell the item. See J. Riley, & W. Samuelson, Optimal Auctions, 71 Am. Econ. Rev. 381-92 (1981).

in setting such a reserve price, the seller runs the risk of losing the sale altogether despite the presence of some bidders that are willing to pay more than the item is worth to the seller. Therefore, by setting the optimal reserve price, the seller is capable of distorting the outcome of the auction away from what would maximize economic efficiency.[24]

IV. "Common" versus "Private Value" Models

Bidders face substantial uncertainty when making decisions regarding how much to bid in an auction. Economic theory has focused on two very different sources of uncertainty for the bidder, each of which causes markedly different bidding behavior. In the first case, each bidder is believed to have its own "private" valuation for the object for sale. Moreover, each bidder perceives that any other bidder's value of the object is drawn from some known probability distribution and that the draws are taken independently of each other.[25] The independence assumption means that there is no unobserved common factor that

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[24] See McAfee & McMillan, Auctions, at 713. See also discussion infra pp. 38-41.

[25] Some auction models relax the "independence" assumption. In such "affiliation" models, as a bidder's estimate of the true value of an object increases, the bidder expects that the bids of other bidders will rise as well. The notion of "affiliation" also occurs in a common values setting. See P. Milgrom, Auction and Bidding: A Primer, 3 J. Econ. Perspectives 3-22 (1989).

causes a correlation between the competitors' bids.[26] The absence of such a correlation ensures that the independence property is preserved.[27] Taken together, these assumptions form the "pure" version of the "independent private values model." Such a model applies, for instance, to situations where bidders are buying for their own use. The auction of artwork not for resale is the prototypical example of a private value setting. However, an aftermarket may exist in a private value setting if the auction fails to assign an item to the bidder that places the highest value on the item.

In the second setting, the item for sale is considered to have a "common" but unknown value to all prospective bidders (i.e., the item's value is the same to all bidders). Each bidder forms an estimate of this unknown common value using its own

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[26] The independence assumption is inconsistent only with the existence of an unobserved common factor that creates a correlation between the competitors' bids. As discussed shortly, such an assumption is not inconsistent with the presence of an unobserved common factor if it does not create such a correlation.

[27] The type of bidding strategies (i.e., the mathematical relationship between a bidder's valuation and its submitted bid) adopted by bidders in a private value auction depend upon the auction mechanism used to allocate the item. For example, in a first-price sealed-bid auction, the optimal bid depends upon the bidding behavior of others. On the other hand, if either a second-price sealed-bid auction or an English auction is used, bidders have the simple dominant strategy of allowing the bidding to reveal their own private value.

"private information."[28] Differences in bids result from differences in the private information possessed by bidders regarding this common value.[29] Importantly, because all bidders place the same value on the item at auction, they must have an equal ability to use the item efficiently. Therefore, from an economic efficiency perspective, it does not matter who the winning bidder is. Moreover, because all bidders place the same value on the item at auction, one would not expect to observe an active aftermarket for the item auctioned.

A common value setting occurs, in general, when the asset offered at auction is of uncertain quality and, moreover, this uncertainty causes a correlation in the bids of the competitors. In such a situation, bidders do not know with certainty the auctioned item's value to them. A frequently cited example of a common value auction is the U.S. Government's Treasury Bill auction, where each bidder is attempting to obtain an accurate estimate of the same value -- the price at which the security

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[28] Auction theory is an application of game theory. Game theory identifies two different types of information -- "common" information and "private" information. A fact is considered common information or knowledge among players in a game if every player knows the fact, every player knows that every player knows it, and so on. A player's private information is any information that he has that is not common information among all the players in the game. See, e.g., R. Myerson, Game Theory: Analysis of Conflict 64 (1991) (Myerson, Game Theory).

[29] Auction theory assumes bidders obtain this private information through information "signals" (i.e., market demand and cost studies). Bidders use these information signals in developing their bidding strategies.

will trade after the auction.[30]

There also exists a "impure" version of the private value model, which combines elements of both the private and common value settings. Consider the following example.[31] Suppose the value that each bidder places on a piece of art depends on its personal valuation of the item and some, common, unknown future market price. Suppose, further, that this unknown future value is uncorrelated with the bidders' personal valuations. In such a situation, the independent private values model still applies because the bids of each bidder are still determined by the respective private values and, moreover, they remain uncorrelated with the bids of other bidders.[32]

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[30] Another frequently cited example of a common values auction is the government's sale of oil exploration leases. It is often referred to as a common value auction because it is assumed that all bidders place the same value on any petroleum that may be discovered on the tract. However, this characterization is too limiting because there exists an active aftermarket for existing or proven petroleum reserves. Such an aftermarket is consistent with a private rather than a common value model. See Smith, Auctions, at 143. Similarly, the existence of an active aftermarket for U.S. Treasury Bills suggest that the bidding for such items may be conducted in a private value setting.

[31] R. McAfee, & J. McMillan, Bidding Rings 82 Am. Econ. Rev. 579-599 (1992) (McAfee & McMillan, Bidding Rings). This example is taken from McAfee & McMillan, Bidding Rings, at 582.

[32] If this uncertainty is weighted differently by bidders or if some bidders have lower uncertainty than other bidders, then the uncertainty is inconsistent with a private value model. See McAfee & McMillan, Bidding Rings, at 582.

Bidders' behavior depends on the source of the uncertainty they face when submitting a bid. For instance, because of uncertainty regarding the true valuation of the common value and the ability of additional information to improve one's estimate of this true value, knowing someone else's valuation of the object auctioned will cause the bidder to change its valuation and, therefore, its bid. In the independent private values model, knowing another bidder's valuation will not cause a bidder to change its valuation, although it may cause the bidder to change its bid.

A. Auction Design: Importance of Common/Private Value Distinction

The issue of common versus private value settings is significant for PCS auction design. Because the PCS auction will be conducted in largely a private value setting, bidding behavior will not be significantly affected by bidder concerns regarding the "winner's curse."[33] Indeed, this issue would not be a factor were it not for the uncertainties that introduce common value elements into the PCS auction.

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[33] The "winner's curse" occurs when a winning bidder discovers it has paid more for the auctioned item than its common prize value. Because it only occurs when a bidder pays more for an item than its common prize value, the winner's curse only occurs in a common value setting. The theoretical literature suggests that the winner's curse should not occur in practice since any bidder can avoid it by shading, in an ascending-bid auction, its bid to take into account that it has over-estimated the value of the auctioned item.

Within a private value setting, the winning bid is an increasing (i.e., monotonic) function of the number of bidders. This occurs because the amount each bidder "pads" its bid decreases with an increase in bidding competition. In a common value setting, while padding decreases initially as the number of bidders increase, padding increases beyond some point as bidders recognize that they become, at higher bids, more susceptible to the "winner's curse."[34] Therefore, beyond some unknown number of bidders, the incremental benefit to revenues of increasing the number of bidders is greater in a private than in a common value setting.

In a common value setting, "joint bidding" -- a single bid submitted on behalf of multiple parties -- is often permitted in order to increase revenues. In such a setting, joint bidding allows firms to exchange information about the auctioned item's "true" value. This exchange of information will increase seller revenue by permitting more aggressive bidding. However, in a private value setting, such information will not induce more aggressive bidding. In this setting, joint bidding will only serve to reduce auction competition.[35]

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[34] See H. Paarsch, Deciding Between the Common and Private Value Paradigms in Empirical Models of Auctions, 51 J. of Econometrics 191-215 (1992).

[35] Joint bidding may also allow a collection of capital-constrained firms to participate in the auction. In these situations, the Commission may consider allowing such bidding. However, under no circumstances should the Commission allow joint bids between non-capital

B. PCS Auction - Common Versus Private Value?

The existence of shared uncertainty is the primary way in which a common value element is introduced into spectrum auctions such as those for PCS.[36] In the case of PCS, bidders are confronted with at least two types of uncertainty. First, uncertainty exists regarding the amount of interference any given licenseholder will receive from other transmissions, such as from incumbent fixed microwave users. This uncertainty is shared among all bidders regarding the value of any given PCS license. Second, bidders are also uncertain about the competitive response their entry into the PCS market will elicit. These two sources of uncertainty are common to all bidders and appear to make it impossible for bidders to know, with certainty, their private values for spectrum licenses. These uncertainties, therefore, introduce a common value element into the PCS auction.

Although the bidding environment in the PCS auction will involve at least some common value elements, a common value model would imply that each bidder places the same value on a given PCS license. This requirement for a common values model is not likely to be satisfied in a PCS auction because of the geographic

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constrained bidders or between non-capital-constrained and capital-constrained bidders.

[36] Bidders face a number of uncertainties when placed in an auction environment. For instance, bidders are typically uncertain as to the number of competing bidders in an auction. The uncertainties described here, however, are those that introduce a common values element into the auction.

and spectrum "value interdependencies" discussed earlier, which give PCS providers an incentive to acquire adjacent franchise areas.[37] This suggests that the value placed by a bidder on one spectrum license depends upon what other geographically adjacent license it has also won. Given this value interdependency, some bidders will place a higher value on a given PCS license than will others.

Moreover, in an auction, the most a bidder is willing to bid for an auctioned item is the item's incremental contribution to profits. For a number of reasons, these contributions will likely vary among bidders. Such variation may be due to differences in the cost structure among the bidders. Certain PCS providers may be able to take advantage of scope economies made possible by their ability to provide multiple services. For instance, long-distance service providers may view PCS as a way of reducing their costs of completing long distance calls. In such cases, the value that those bidders place on a spectrum license will likely differ substantially from the value placed by other bidders.

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[37] The Commission has decided to use Basic Trading Areas (BTAs) as the unit of auction for five of the seven PCS licenses that it is awarding per geographic area. According to Rand McNally, BTAs are based upon consumer purchasing decisions regarding clothing and related articles. Because BTAs do not correspond to the area that serves as a center of general economic activity, the demand to roam between BTAs will likely be large in some instances.

In summary, a PCS auction will contain elements of both a private and common value auction. However, the nature of these elements suggests that the PCS auction will be conducted in an "impure" private value setting. The common value elements of the PCS auction are derived from uncertainties faced by all bidders. Moreover, these uncertainties appear to be independent of the private value each bidder places on such a license.

V. "Bidder Asymmetry"

In designing an auction model, the theorist can either assume that each bidder obtains its personal valuation for the item from the same probability distribution, or that bidders obtain their valuations from different distributions.[38] When the former is assumed, any two bidders with the same valuation will submit the same bid. When the latter is assumed, any two bidders that obtain their personal valuations from different distributions will submit different bids despite having the same valuation. The phrase "bidder symmetry" describes the situation where bidders obtain their valuations from the same probability distribution.[39] In contrast, the phrase "bidder asymmetry"

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[38] More formally, if it is appropriate to represent all bidders as drawing their valuations for an object from the same probability distribution F, symmetry obtains. If, on the other hand, different groups of bidders draw their valuations from different distributions F_i, $i=1,2,...n$, asymmetry among bidders is said to exist.

[39] In discussing probability distributions we compare only mean values, and thus, we make the implicit assumption that "high" and "low" distributions are alike in all

describes the case where bidders obtain their valuations from different probability distributions.[40] Importantly, the four primary auction forms are not equivalent in terms of economic efficiency or revenues when bidder asymmetry exists. Because we assume that PCS auctions will occur in a private value setting, we will discuss bidder asymmetry from a private value perspective.[41]

In the single unit auction environment, the effect of bidder asymmetry on an auction's capacity to be economically efficient and to generate revenue varies among auctions. In particular, when asymmetries are present, two types of mechanisms under consideration by the Commission -- the first-price sealed bid and the English oral auction -- differ in terms of economic

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other respects (i.e., variance, skewness, and kurtosis). We do this merely for expositional simplicity.

40 See McAfee & McMillan, Bidding Rings, at 709. Auction theorists often state that bidder asymmetry exists when all bidders do not appear the same to the seller and to each other. More technically, this means that bidders employ different bid functions when formulating their bids.

41 As noted, the private- versus common-value distinction depends upon whether a bidder's personal valuation is determined by an underlying common value for the auctioned object among bidders or simply by the bidder's own private value. In contrast, bidder asymmetry exists when, for a collection of bidders, bids are not the same increasing function of one's personal valuation. In such a case, any two bidders with the same valuation will not submit the same bid. Therefore, not only are the concepts of bidder symmetry and common versus private models different, they are complementary in the sense that both are needed in order to completely describe the bidding environment.

efficiency and expected revenue. Theory suggest that the English auction's expected price can be either higher or lower than the first-price sealed-bid auction's expected price, but that the two prices are generally not the same.[42] Moreover, it appears that economic efficiency is maximized for the English as opposed to the first-price sealed-bid.[43] It is unclear whether these results obtain in auctions for multiple units with strong value interdependencies (e.g., PCS auctions).

Bidder asymmetries arise in the context of PCS in at least three different ways. First, the FCC has decided to allow each cellular telephone operator to bid for one 10 MHz PCS license in areas where they currently provide cellular telephone service. Due to the economic rents earned by existing cellular providers, at least some forms of PCS service are likely to be close

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[42] See, Vickrey, Counterspeculation, at 8-37, or E. Maskin & Eric J. Riley, Auction Theory with Private Values, 75(2) Am. Econ. Rev. 150-55 (1985).

[43] The intuition behind this result is as follows. In a first-price sealed-bid auction, higher-valuation bidders submit higher bids than other bidders within the same "class" (i.e., bidders drawing their valuations from the same distribution). However, this is generally not the case across classes because bidders from different classes perceive themselves to be facing different degrees of bidding competition. The possibility arises that the bidder with the highest valuation underestimates the bidding competition, and thus loses the auction. The first-price sealed-bid auction, therefore, can yield an inefficient outcome. In an English auction, however, the oral, continuous nature of the auction presents an opportunity to the bidder with the highest valuation to correct any misperceptions about bidding competition. See McAfee & McMillan, Auctions, at 714-5.

substitutes for cellular service.[44] In addition, because competition lowers industry profits, a PCS license is more valuable to an incumbent cellular operator than it is to a potential entrant.[45] This implies that incumbent cellular providers obtain their PCS license valuations from a probability distribution with a higher mean than non-incumbent cellular providers. Because of this "asymmetry," it is likely that an incumbent cellular operator will win the one 10 MHz license for which it can bid.

A second type of asymmetry may arise if different segments of the bidding population plan to use PCS licenses in different ways. For instance, if one group of bidders has a more innovative vision for PCS than another, then it would be appropriate to represent that group as drawing its valuations from a distribution with a different mean value. However, such an asymmetry is not likely to occur if, for example, all entrants plan to provide a service quite similar to cellular service.[46]

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[44] See U.S. General Accounting Office, GAO/RCED-92-220, Concerns About Competition in the Cellular Telephone Service Industry 26-27 (July, 1992).

[45] See R. Gilbert & R. Newbery, Preemptive Patenting and the Persistence of Monopoly, 72 Am. Econ. Rev. 514-26 (1982).

[46] Our discussions with some prospective bidders indicate that, in general, they plan to use broadband PCS licenses to provide a service that is a close substitute to cellular service.

A third type of asymmetry may arise due to "capital-constrained" bidders. Minorities, for example, have typically suffered from limited access to capital markets. Recent empirical research indicates that blacks, on average, receive smaller bank loans than whites after controlling for a number of factors including age, educational background, and possession of equity capital.[47] Minority bidders for PCS licenses are likely constrained in ways non-minority bidders are not. This research suggests, therefore, that minority bidders draw their valuations from a distribution with a lower mean value than non-minority bidders.

From an efficiency perspective, asymmetry presents a problem if high valuation bidders underestimate the bidding competition they face.[48] In general, however, it is unlikely that a bidder with the highest valuation for a license will draw its value from a distribution with a lower mean value (i.e., small businesses and businesses owned by minorities and women). As a result, if the Commission's sole concern is to maximize efficiency, asymmetry would likely present only minor problems.[49]

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[47] See Timothy Bates, Banking on Black Enterprise, 74 Joint Center for Political and Economic Studies (1993); Faith Ando, An Analysis of Access to Bank Credit, UCLA Center for African-American Studies (1988).

[48] In oral auctions where bidders can respond to other bidders, this concern can be completely dismissed.

[49] We recognize that social welfare is not always maximized if the bidder that values an item most highly wins an auction. For example, the acquisition of PCS licenses by

Of course, the Commission must consider factors other than efficiency in assigning PCS licenses. The Commission has a statutory mandate to ensure participation in the provision of spectrum-based services by small businesses, rural telephone companies, and businesses owned by women and minorities, at least some of which have low-valuation distributions because of capital constraints. For these entities, bidder asymmetries may make such a mandate difficult to satisfy in the PCS license bidding process.

The Commission has potentially alleviated some policy concerns stemming from asymmetry with the proposals in the Notice. For example, the limitation on in-region cellular participation in PCS auctions will help alleviate the incumbent-entrant asymmetry. Because of the cost associated with bidding, combined with the low probability of winning, rational entrants may choose to avoid bidding against cellular incumbents for the one 10 MHz license within a geographic area for which cellular interests can bid.

The Commission's plan to set aside one 20 MHz license in the lower band and one 10 MHz license in the upper band for "designated entities" -- small businesses, rural telephone

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existing cellular providers may create excessive market power, thus reducing economic welfare compared with a different assignment. This situation provides a different sort of problem for the Commission.

companies, and businesses owned by women and minorities[50] -- may permit some capital-constrained bidders to bid only against each other.[51] Of course, capital-constrained bidders who participate in auctions for non-set-aside licenses are likely to confront asymmetry.[52] One way to help such designated entities is to permit them to pay winning bids in installments. Because installments make capital constraints less binding, designated entities may be able to compete for PCS licenses with non-capital-constrained firms on a more even level. More aggressive bidding on the part of designated entities, moreover, may increase governmental revenues in auctions where bidding competition would otherwise have been weaker.

Another possible remedy for revenue concerns stemming from bidder asymmetry is to force groups drawing values from a distribution with a higher mean to bid some fixed percentage more than those drawing values from a distribution with a lower mean. This is another way to help the Commission satisfy its obligation to aid capital-constrained bidders. The intuition underlying this strategy is that by leveling the playing field between the

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50 See Notice, paras. 72-78.

51 It is possible that rural telephone companies may face less severe capital constraints than some of the other parties.

52 Because the Commission intends to make bidders pay an application fee, it is likely that rational capital-constrained bidders would not participate in auctions for non-set-aside licenses that they have little or no hope of winning.

two types of bidders, the seller increases the number of bidders with real potential to win the auction, and thus forces high distribution bidders to increase their bids.[53] Because the expected winning bid in a private value setting increases with the number of bidders, this remedy might increase expected revenue. Unfortunately, because the seller runs the risk of awarding the license to someone other than the bidder with the highest valuation, this strategy suffers from an efficiency perspective. In addition, this remedy begs the question as to how one arrives at the appropriate overbid percentage.[54]

However, because the Commission's restrictions on cellular participation and its proposed set-asides will likely reduce at least some of the policy concerns associated with bidder

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[53] See McAfee & McMillan, Auctions, at 715. Again, these results pertain to a single-unit auction. It remains unclear whether such results obtain in auctions for multiple units with potential combinatorial features.

[54] McAfee and McMillan point out that this strategy has been employed in government procurement: "Under buy-American legislation, the United States federal government offers a 6 percent price preference for domestic content: If a local firm's bid is no more than 6 percent higher than the lowest foreign bid, the local bid will be accepted." See McAfee & McMillan, Auctions, at 716. One doubts, however, that this strategy was employed to deal with bidder asymmetry. This remedy is only effective in increasing bidding competition if the seller can prevent the successful bidder from reselling the object to another bidder. Otherwise, a non-favored entity will allow favored bidders to win the auction at a low price, and then buy the item later at a price lower than if it had won the auction, but higher than its value to the favored entity.

asymmetry, the remedy spelled out in the previous paragraph is probably not necessary. In particular, to the extent that different uses of the spectrum do not constitute a major source of asymmetry, the set-asides and the cellular limitation are likely to draw together bidders who derive their valuations from similar distributions. Notice however, that in solving the bidder asymmetry problem the Commission may have seriously reduced the number of bidders in any given auction, thereby creating a number of other problems.

VI. Bidding Competition

The Commission's treatment of "designated entities" alleviates some asymmetry issues. However, the economic efficiency and revenue generating characteristics of the PCS auction depend, in part, upon the extent of the bidding competition for PCS licenses. The Commission's decision to impose eligibility restrictions, both on cellular participation and through set-asides for designated entities, potentially reduces the number of bidders in an auction for a given license. Moreover, this potential decline in bidding competition is exacerbated by the multiple-unit nature of the PCS auction. For example, a decline in the overall number of bidders in a geographic area from 15 to 10 is much more serious when seven, rather than one, PCS licenses are available at auction.[55]

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[55] As discussed below, the Commission's proposed auction form fails to promote competition among existing bidders. The Commission's proposed auction form attempts to

A reduction in the number of bidders increases the likelihood of collusive bidding behavior. The extent to which bidders can engage in such bidding depends on the nature of the auction. For instance, thousands of PCS licenses will be offered at auction. If these licenses are assigned sequentially, the successive (i.e., repeated) nature of this "game" allows collusive bidders to adopt the strategy of threatening to retaliate against defectors by reverting to noncooperative behavior in successive PCS auctions.[56] Other auction forms, such as "simultaneous" auctions, have better collusion-prevention characteristics.[57]

Finally, lack of bidding competition can have unfavorable effects on revenue by increasing, on average, the discrepancy between the first highest and second highest bid, thereby reducing seller revenue.[58] Two methods of combatting the possibility of decreased revenue where bidding is not competitive are discussed below.

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capture value interdependencies among PCS licenses in a relatively crude fashion. See discussion infra pp. 49-66.

[56] See McAfee & McMillan, Auctions, at 724. There are numerous other factors that determine whether collusive bidding is a stable outcome. See McAfee & McMillan, Bidding Rings, at 579-99.

[57] In a simultaneous auction, multiple items are auctioned at the same time. See infra at pp. 51-56 for an example of a simultaneous multiple-unit auction.

[58] See McAfee & McMillan, Auctions, at 711.

A. Reserve Prices

A reserve price is one way to "protect" revenue in the event of uncompetitive or "thin" bidding for PCS licenses. The consequences of not employing a reserve price in the presence of low bidding competition were observed in spectrum auctions in both Great Britain and New Zealand. In Great Britain, bidders for some television franchise licenses obtained such licenses for trivial sums.[59] There, Great Britain did not use a reserve price but, as discussed below, attempted to use a royalty scheme. Similarly, in New Zealand, low bidder competition caused a wide discrepancy between the first and second highest bids, and also allowed some bidders to obtain their spectrum licenses for small amounts.[60]

On the other hand, a reserve price properly set to increase revenue creates the possibility that a PCS license may go unassigned despite the fact that there may be at least one bidder that values the license more than the seller. Therefore, such a reserve price may distort the assignment of PCS licenses away from that which would enhance economic efficiency.

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[59] For example, Central Television makes an annual payment of only £2,000 (plus a fixed percentage of revenues) for its East, West, and South Midlands franchise. See The Economist, Oct. 19, 1991, at 67.

[60] Not only was there a large discrepancy between the two bids, but the second bid was sometimes very low. See Milton Mueller, New Zealand's Revolution in Spectrum Management, 27-29 (International Center for Telecommunications Management, Univ. of Nebraska at Omaha), (1991).

B. Royalty Rates

By tying eventual payment to the actual revenues generated by an asset, a royalty can increase a seller's overall payment, especially when markets are thin. The U.S. Government has used royalty rates in auctioning offshore oil tracts. There are numerous ways in which a royalty rate can be incorporated into the auction mechanism. However, the most common method involves the seller setting the royalty rate and calling for bids on an up-front payment. Unlike New Zealand, Great Britain employed a royalty rate in its spectrum auctions and thus recovered some revenues lost to thin markets. Each year winning bidders pay an amount equal to their winning bid plus a fixed percentage (10-15%) of their annual revenues. While it may seem difficult to compute revenues and thus royalties for spectrum users, it is interesting to note that the U.S. Government has used similar arrangements in weapons procurement. The Department of Defense has used incentive contracts, which "make payment to the contractor depend not only on [its] bid but also on the production cost [it] actually incurs."[61]

To avoid unnecessary complications, if the Commission were to employ a royalty, it should first specify a fixed royalty rate and then compare up-front bids for a license to determine the

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[61] McAfee and McMillan, Auctions, at 717. See Peter DeMayo, Bidding on New Ship Construction in Auctions, Bidding, and Contracting: Uses and Theory 371-87 (R. Engelbrecht-Wiggans, M. Shubik, & R Stark eds.) (NY: NYU Press) (1983).

license winner. By contrast, if the Commission allowed bids on both up-front payments and the royalty rate, determining the most attractive bid would be quite difficult. Unfortunately, determining an "optimal" fixed royalty rate is also difficult.[62] Moreover, the use of a royalty rate may be complicated by difficulties in monitoring a PCS provider's revenues. In any event, the more general point is that, in remedying bidder asymmetries, the Commission's proposals may result in thin auction markets. To the extent that the Commission is concerned about revenue, these thin markets pose a problem that must be met with either a reserve price or a royalty.

VII. "Bidder Risk Aversion"

Both theorists and empirical investigators have been concerned about the effects of bidder risk aversion on auction outcomes. Theoretically, uncertainty arises in auctions in a private values context because individual bidders know only their own valuation and the distribution from which other bidders draw their valuations.[63] Given this limited information, a bid that maximizes expected value may be too low to win the auction.

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[62] Because the royalty payment depends on the revenues generated by the licensee, moral hazard problems occur when royalty rates are "too high." For example, if the royalty rate was 100%, the licensee would have no incentive to generate revenue since it would not earn anything from its efforts.

[63] The assumption regarding a bidder's knowledge about the distribution from which other bidders draw their valuations is a useful simplification.

Bidders who dislike uncertainty sufficiently may be willing to submit a bid higher than that which maximizes expected profits. Such bidders trade off dollars for an increased probability of winning (i.e., increased certainty). In the context of auctions, such bidders are said to be "risk averse."

Experimental work conducted in a laboratory setting suggests risk aversion may play a role in bidding behavior. For example, in various first-price sealed-bid laboratory experiments, subjects exhibited bidding behavior consistent with a risk aversion hypothesis.[64] However, the same investigators found subject bidding behavior to be consistent with risk-neutral predictions in English, Dutch, and second-price sealed-bid auctions.[65] In field studies on bidding for drainage tract leases for oil, bidding behavior was found to be consistent with risk neutral bidding predictions.[66] Significantly less field research has been conducted on bidding behavior in a private value setting. The laboratory experiments do, however, suggest that risk aversion may affect bidding behavior, at least in first-price sealed-bid auctions.

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[64] In each of these experiments, subjects were given an independently drawn private value.

[65] See Douglas Davis & Charles Holt, Experimental Economics 384-87 (Princeton, NJ: Princeton Univ. Press) (1993).

[66] See K. Hendricks & R. Porter, An Empirical Study of an Auction with Asymmetric Information, 78 Am. Econ. Rev. 865-83 (1988); K. Hendricks, R. Porter, & R. Spady, Random Reservation Prices and Bidding Behavior in OCS Drainage Auctions, 32 J of Law & Econ. 83-105 (1989).

Risk averse bidders present a seller with both opportunities and problems. On the one hand, opportunities arise because risk averse bidders can increase revenue by forcing high valuation bidders to bid closer to their true private value in order to win the auction. On the other hand, in the case of the first-price sealed-bid mechanism, the seller runs the risk of awarding the item to someone other than the bidder with the highest valuation.[67] In the single-unit case with risk averse bidders, the first-price sealed-bid produces a larger expected revenue than the English or second-price sealed-bid auction.[68] The seller must, therefore, make a choice between expected revenue and economic efficiency. Because the highest valuation bidder has the opportunity to respond to risk averse bidders in an English auction, it will always obtain the item, but at a price higher than if it faced only risk-neutral bidders in a first-price sealed-bid auction.[69] A seller concerned primarily about economic efficiency would choose the English auction over the

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[67] Because a risk averse bidder with, for instance, the second highest valuation, is willing to trade reduced surplus from obtaining the auctioned item for increased certainty, such a bidder may be able to outbid a risk neutral bidder with the highest valuation.

[68] McAfee & McMillan, Auctions, at 719. See M. Harris & A. Raviv, Allocational Mechanisms and The Design of Auctions, 75(2) Econometrica 1477-99 (1981); C. Holt, Competitive Bidding for Contracts Under Alternative Bidding Procedures, 88(3) J. of Political Econ. 433-45 (1980); J. Riley & W. Samuelson, Optimal Auctions, 71(3) Am. Econ. Rev. 381-92 (1981).

[69] Note that a rational risk averse bidder would never bid in excess of its private value.